

NACA RM L50K10

CONFIDENTIAL

NACA

# RESEARCH MEMORANDUM

THE EFFECT OF MASS DISTRIBUTION ON THE LOW-SPEED DYNAMIC  
LATERAL STABILITY AND CONTROL CHARACTERISTICS OF  
A MODEL WITH A 60° TRIANGULAR WING

By Joseph L. Johnson

Langley Aeronautical Laboratory  
Langley Field, Va.

CLASSIFICATION CHANGED

~~CONFIDENTIAL~~

By authority of *W. C. ...* Date *12/11/53*

This document contains classified information affecting the National Defense of the United States within the meaning of the Espionage Act, USC 50:81 and 32. Its transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law.

Information so classified may be imparted only to persons in the military and naval services of the United States, appropriate civilian officers and employees of the Federal Government who have a legitimate interest therein, and to United States citizens of known loyalty and discretion who of necessity must be informed thereof.

NATIONAL ADVISORY COMMITTEE  
FOR AERONAUTICS

WASHINGTON

March 9, 1951

UNCLASSIFIED

~~CONFIDENTIAL~~

RESTRICTED

CLASSIFICATION CANCELLED

Authority *NACA K7 2590* Date *8/31/54*

See

*204 9/15/54*

~~SECRET~~ UNCLASSIFIED

## NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

## RESEARCH MEMORANDUM

THE EFFECT OF MASS DISTRIBUTION ON THE LOW-SPEED DYNAMIC  
LATERAL STABILITY AND CONTROL CHARACTERISTICS OF  
A MODEL WITH A 60° TRIANGULAR WING

By Joseph L. Johnson

## SUMMARY

An investigation to determine the effect of mass distribution on the dynamic lateral stability and control characteristics of a model with a 60° triangular wing has been conducted in the Langley free-flight tunnel. The moments of inertia in roll and yaw were increased to correspond to those of a triangular-wing fighter-type airplane with wing tanks. Flight tests and calculations were made for five different loading conditions.

The investigation showed the following effects of increased rolling and yawing moments of inertia: a decrease in the oscillatory stability of the model; and a decrease in the rolling acceleration, which caused a lag in the response of the model to control and increased the time required for the model to reach a given angle of bank. The general flight behavior became worse as the inertias were increased and the predominant factor affecting the pilot's opinion of the general flight behavior appeared to be the lateral controllability and not the oscillatory stability. The change in the lateral-stability derivatives produced by the particular wing-tank configuration used in the tests caused an improvement in oscillatory stability that partly counteracted the detrimental effect of the increased inertia on the oscillatory stability. The calculations indicated that increasing the altitude from sea level to 30,000 feet caused the time required for the lateral oscillation to damp to one-half amplitude to be approximately doubled for all conditions.

## INTRODUCTION

In recent years the trend in airplane design has been such as to cause a large increase in rolling and yawing moments of inertia. This increase in moments of inertia has been brought about by locating engines,

~~SECRET~~  
UNCLASSIFIED

fuel tanks, and armament along the wing. Several theoretical and experimental studies have been made in the past to determine the effect of increases in moments of inertia on the lateral stability characteristics of airplanes with unswept wings, and the results of these investigations showed that a marked decrease in stability generally occurs with large increases in inertia (references 1, 2, and 3). As an extension to this work, two investigations have been conducted in the Langley free-flight tunnel to determine the effects of large increases in rolling and yawing moments of inertia on the lateral stability characteristics of configurations having sweptback and triangular wings. One of these investigations (reference 4) was concerned with the effect of both independent and simultaneous changes in the rolling and yawing inertias on the lateral stability characteristics of an aspect ratio 4, taper ratio 0.5,  $45^\circ$  swept-back wing. The present paper gives the results of an investigation to determine the effects of simultaneous changes in rolling and yawing inertias on the lateral stability characteristics of a model with a  $60^\circ$  triangular wing.

This investigation included flight tests to determine the lateral stability and control characteristics of the model for a number of loading conditions, most of which simulated the loading of the airplane with wing tanks on. Calculations to determine the period and the time to damp to one-half amplitude of the lateral oscillation were made for the model at each loading condition at sea level and 30,000-foot altitude. The calculated rolling motion resulting from a disturbance in roll was also made for the model at each loading condition at sea level.

#### SYMBOLS

S	wing area, square feet
$\bar{c}$	mean aerodynamic chord, feet
V	airspeed, feet per second
b	wing span, feet
q	dynamic pressure, pounds per square foot
$\rho$	air density, slugs per cubic foot
W	weight, pounds
m	airplane mass, slugs
$\mu_b$	relative density factor ( $m/\rho S b$ )

$\beta$	angle of sideslip, degrees
$\psi$	angle of yaw, degrees
$\phi$	angle of bank, degrees
$\alpha$	angle of attack of reference axis (fig. 1), degrees
$\eta$	angle of attack of principal longitudinal axis of airplane, positive when principal axis is above flight path at nose (fig. 1), degrees
$\epsilon$	angle between reference axis and principal axis, positive when reference axis is above principal axis at nose (fig. 1), degrees
$\theta$	angle between reference axis and horizontal axis, positive when reference axis is above horizontal axis at nose (fig. 1), degrees
$\gamma$	angle of flight to horizontal axis, positive in a climb (fig. 1), degrees
$I_{X_0}$	moment of inertia about principal longitudinal axis, slug-ft <sup>2</sup> $\left( \frac{mk_{X_0}^2}{2} \right)$
$I_{Z_0}$	moment of inertia about principal vertical axis, slug-ft <sup>2</sup> $\left( \frac{mk_{Z_0}^2}{2} \right)$
$k_{X_0}$	radius of gyration about principal longitudinal axis, feet
$k_{Z_0}$	radius of gyration about principal vertical axis, feet
$K_{X_0}$	nondimensional radius of gyration about principal longitudinal axis $(k_{X_0}/b)$
$K_{Z_0}$	nondimensional radius of gyration about principal vertical axis $(k_{Z_0}/b)$
$K_X$	nondimensional radius of gyration about longitudinal-stability axis $\left( \sqrt{K_{X_0}^2 \cos^2 \eta + K_{Z_0}^2 \sin^2 \eta} \right)$

$K_Z$	nondimensional radius of gyration about vertical-stability axis $\left( \sqrt{K_{Z_0}^2 \cos^2 \eta + K_{X_0}^2 \sin^2 \eta} \right)$
$K_{XZ}$	nondimensional product-of-inertia parameter $\left( (K_{Z_0}^2 - K_{X_0}^2) \cos \eta \sin \eta \right)$
$C_n$	yawing-moment coefficient (Yawing moment/qSb)
$C_l$	rolling-moment coefficient (Rolling moment/qSb)
$C_y$	lateral-force coefficient (Lateral force/qS)
$C_{Y\beta}$	rate of change of lateral-force coefficient with angle of sideslip, per radian $(\partial C_y / \partial \beta)$
$C_{n\beta}$	rate of change of yawing-moment coefficient with angle of sideslip, per radian $(\partial C_n / \partial \beta)$
$C_{l\beta}$	rate of change of rolling-moment coefficient with angle of sideslip, per radian $(\partial C_l / \partial \beta)$
$C_{Yp}$	rate of change of lateral-force coefficient with rolling-angular-velocity factor, per radian $\left( \partial C_y / \partial \frac{pb}{2V} \right)$
$C_{lp}$	rate of change of rolling-moment coefficient with rolling-angular-velocity factor, per radian $\left( \partial C_l / \partial \frac{pb}{2V} \right)$
$C_{np}$	rate of change of yawing-moment coefficient with rolling-angular-velocity factor, per radian $\left( \partial C_n / \partial \frac{pb}{2V} \right)$
$C_{lr}$	rate of change of rolling-moment coefficient with yawing-angular-velocity factor, per radian $\left( \partial C_l / \partial \frac{rb}{2V} \right)$
$C_{Yr}$	rate of change of lateral-force coefficient with yawing-angular-velocity factor, per radian $\left( \partial C_y / \partial \frac{rb}{2V} \right)$
$C_{nr}$	rate of change of yawing-moment coefficient with yawing-angular-velocity factor, per radian $\left( \partial C_n / \partial \frac{rb}{2V} \right)$

l	longitudinal distance rearward from center of gravity to center of pressure of vertical tail, measured parallel to longitudinal stability axis, feet
z	vertical distance upward from center of gravity to center of pressure of vertical tail measured perpendicular to longitudinal stability axis, feet
p	rolling angular velocity, radians per second
r	yawing angular velocity, radians per second
P	period of oscillation, seconds
$T_{1/2}$	time for amplitude of oscillation to decrease to half amplitude
$C_{1/2}$	cycles for amplitude of oscillation to decrease to half amplitude

#### APPARATUS

The experimental part of the investigation was conducted in the Langley free-flight tunnel which is designed to test free-flying dynamic models. A complete description of the tunnel and its operation is presented in reference 5. Force tests to determine the aerodynamic characteristics of the model were made on the six-component balance described in reference 6.

The model used in the tests had a triangular wing with 60° sweepback and an aspect ratio of 2.3. A three-view drawing of the model is presented in figure 2 and mass and aerodynamic characteristics are shown in table I.

The moments of inertia of the model were increased by adding lead weights at different locations on the model. For some loading conditions the weights were placed directly on the wing and fuselage, whereas, for other conditions, they were located in wing tanks or on a rod extending outboard of the wing along the Y axis.

#### RANGE OF VARIABLES

All flight tests and calculations were made for a lift coefficient of 0.65 and for a center-of-gravity position of 25 percent M.A.C. Five different loading conditions were studied in this investigation. The weight (and, therefore, the relative density factor  $\mu_p$ ) increased for

most conditions as the moments of inertia were increased. The five loading conditions used in the investigation were:

1. No ballast weights (basic model)
2. Ballast weights on the nose of fuselage and on the wing tips
3. Ballast weights on rods extending outboard along the Y axis
4. Ballast weights in external-wing tanks suspended below the wing
5. Ballast weights on the wing at the chordwise location of the wing tanks (calculations only)

The mass and aerodynamic parameters for these conditions are given in table I. Each of the conditions except condition 1 was investigated at an intermediate loading and a maximum loading. The intermediate loadings did not have the same moments of inertia for each condition but the maximum loadings had a moment of inertia in roll of 0.16 slug-ft<sup>2</sup> for all conditions. The moment of inertia in yaw was approximately the same for all the heavy conditions except condition 2b. (See table I.)

The values of the inertia parameters for the different loading conditions tested are presented in graphical form in figure 3. Condition 1 corresponds to the normal loading of a triangular-wing fighter airplane. Condition 2 represents the moments of inertia of the airplane having heavy loading along the fuselage as well as along the wing. This condition gave the largest value of  $I_{Z_0}$  of any of the conditions studied. In condition 3 the ballast weight was shifted outboard along the wing so that the weight and relative-density factor remained constant as the moments of inertia were increased. The moments of inertia in condition 4 were increased by the use of external-wing tanks. The wing tanks caused the lateral-stability derivatives for this condition to be different from those for the other conditions. In order to determine the effect of this difference in stability derivatives, calculations were made for condition 5 which had the same mass characteristics as condition 4 but which had stability derivatives for the model with tanks off.

## METHODS

### Calculations

Calculations were made to determine the period and time to damp to one-half amplitude of the lateral oscillation and the time to damp to one-half amplitude for the aperiodic modes at sea level and 30,000-foot altitude by the method presented in reference 7. Calculations were also

made by the method presented in references 8 and 9 to determine the rolling motion resulting from a rolling-moment coefficient of 0.01 applied for 0.4 second in one direction and then reversed for 0.4 second. These calculations were made only for conditions 1, 2b, 3b, 4b, and 5b.

The aerodynamic and mass characteristics used in the calculations are presented in table I. Values of  $C_{Y\beta}$ ,  $C_{n\beta}$ , and  $C_{l\beta}$  were obtained from force tests made in the Langley free-flight tunnel. The tail-off values of  $C_{n_r}$  and  $C_{l_r}$  were estimated from reference 10. The contribution of the tail to the stability derivatives  $C_{n_r}$  and  $C_{l_r}$  were estimated from the equations given in the footnote of table I which are similar to those given in references 2 and 11. Values of  $C_{l_p}$  were estimated from reference 12 and from unpublished data obtained from rotary tests made in the Langley 20-foot free-spinning tunnel. The increase in the value of  $C_{l_p}$  produced by the wing tanks was estimated from the increase in  $C_{L\alpha}$  measured in force tests. The value of  $C_{n_p}$  for the model was estimated from reference 12 and from unpublished data obtained from rotary tests in the Langley 20-foot free-spinning tunnel.

#### Testing Procedure

The model was flown at all the loading conditions given in table I with the exception of condition 5 and the stability, control, and general flight behavior were noted by the pilot. Motion-picture records were also made of the flights to supplement the visual observations of the pilot. Graduated ratings for the oscillatory stability, lateral control, and general flight behavior were given by the pilot for each loading condition flown. The rating system used is shown in table II. The oscillatory stability characteristics were judged by the pilot from the damping of the lateral oscillations after a disturbance. The lateral control characteristics were judged by the pilot from the response of the model in roll to application of the lateral controls. The general flight-behavior ratings, which were based on the over-all flying characteristics of the model, indicate the ease with which the model could be flown, both for straight and level flight and for performance of the mild maneuvers possible in the free-flight tunnel.

The model was flown both with coordinated aileron and rudder control and with ailerons-alone control. Aileron deflections of  $\pm 10^\circ$  and a rudder deflection of  $\pm 5^\circ$  were used for all conditions. In addition, some of the tests of condition 3 were made with aileron deflections of  $\pm 13^\circ$ .



## RESULTS AND DISCUSSION

The results of the investigation are summarized in table II in the form of pilot's ratings for oscillation damping, lateral control, and general flight behavior of the model for the conditions investigated. The results of calculations for correlation with the results of flight tests are presented in table II and in figures 4 to 6.

The results of the investigation are discussed in terms of the moments of inertia,  $I_{X_0}$  and  $I_{Z_0}$ , rather than in terms of the basic mass and mass-distribution parameters,  $\mu_b$ , the relative-density factor, and  $K_{X_0}$  and  $K_{Z_0}$ , the radii of gyration. This method of discussion was used because the variations in  $\mu_b$ ,  $K_{X_0}$ , and  $K_{Z_0}$  were not systematic, whereas the resulting changes in moments of inertia were more systematic and appeared to be consistent in most cases with the observed effects on damping, controllability, and general flight behavior. It should be pointed out, however, that increases in moments of inertia may be accomplished by changes in the radii of gyration, by changes in the mass, or by a combination of the two. In this investigation, the increases in moments of inertia were generally accompanied by an increase in mass and, hence, of the relative-density factor  $\mu_b$ . As can be seen from the effect of increasing the altitude, increases in relative density are detrimental to the stability. The results given in cases in which the moment of inertia changes included weight changes, therefore included relative-density effects as well as strictly inertia effects. The values of  $\mu_b$ ,  $K_{X_0}$ , and  $K_{Z_0}$  for all the test conditions are presented in table I so that the results can be interpreted in terms of these variables if desired.

### Oscillatory Stability

The flight tests showed that the lateral oscillations of the model without ballast weights were well damped and that the oscillatory stability was satisfactory. When the moments of inertia were increased, the oscillatory stability decreased for all conditions investigated as shown by the damping ratings of table II. The greatest decrease in damping occurred for conditions 2 and 3 in which the oscillations were lightly damped and of relatively large amplitude. The smallest decrease in damping occurred for condition 4 in which the oscillations were fairly well damped and of small amplitude. Although the damping decreased for all the conditions investigated, it appeared to the pilot that the damping did not become unsatisfactory for any condition.

The results of calculations made to determine the damping characteristics are presented in figure 4. These results are in agreement with

the flight tests in that they show that the damping decreased as the moments of inertia were increased for all the conditions investigated, with conditions 2 and 3 showing the greatest decrease in damping and condition 4 showing the smallest decrease in damping. Condition 5 showed a greater decrease in damping than that for condition 4 but not as great as that for condition 2.

The damping for condition 2b is only slightly less than that for condition 3b despite the fact that condition 2b had a much larger value of  $I_{Z_0}$ . This result, which indicates that changes in  $I_{X_0}$  affect the oscillatory stability much more than changes in  $I_{Z_0}$ , is in agreement with the results presented in reference 4.

The calculations indicate that removing the wing tanks and placing ballast weights on the wing at the wing tanks location (condition 4 to condition 5) greatly reduced the damping. Since these conditions had approximately the same mass parameters, this difference in damping can be attributed directly to the effect of the wing tanks on the stability derivatives of the model.

In general, it appeared to the pilot that the damping of the model in flight tests was somewhat better than that predicted by the calculations. This impression was probably gained partly as a result of the fact that, because of the limited space in the tunnel, the model cannot be allowed to fly uncontrolled for long enough periods of time to permit a very accurate evaluation of the damping. Reasonably good agreement was obtained, however, between the pilot's opinion and the calculations regarding the trends in damping produced by the changes in inertia.

A comparison of the calculated scaled-up damping and period characteristics of the model with the U. S. Air Force and Navy flying-qualities requirements for satisfactory damping of the lateral oscillation (references 13 and 14) is presented in figure 5. The values presented were scaled up so that the configuration tested corresponded to a  $\frac{1}{12}$ -scale model of a 31.3-foot-span airplane. The results of figure 5 show that all the sea-level conditions were marginal or unsatisfactory except for the basic condition and the intermediate wing-tank condition 4a. The damping characteristics of the model in the flight tests, however, were considered to be at least fair for all conditions although these points were found to be unsatisfactory on the basis of the flying-qualities requirements. (See table II.) The data of figure 5 show that increasing the altitude from sea level to 30,000 feet caused the time required for the lateral oscillation to damp to one-half amplitude to be approximately doubled for all conditions. As a result of this decrease in stability, all the conditions with the exception of condition 1 were unsatisfactory on the basis of the flying-qualities requirement.

## Lateral Control

The model in condition 1 was observed to respond rapidly to control deflections when flown with either ailerons alone or ailerons coordinated with the rudder. There was some slight evidence of adverse yawing due to aileron deflection, however, when ailerons alone were used for control. Increasing the moments of inertia made the lateral control worse for all the conditions investigated as indicated by the control ratings of table II. The control characteristics for conditions 2b, 3b, and 4b were considered unsatisfactory with condition 3b showing the greatest effect of increased inertia. Flight tests indicated that the increased inertias for the model in the high-inertia conditions reduced the rolling acceleration which caused a lag in the response of the model to control and increased the time required for the model to reach a given angle of bank or to return to a wing-level attitude. The model also had a tendency to overshoot after a corrective control was applied and this tendency made steady-wing level flights difficult to attain once the model was disturbed. It appeared to the pilot that, for a given amount of control, the model responded more slowly to control deflections in condition 3b than in condition 2b despite the fact that these two conditions had the same rolling moments of inertia and stability derivatives. The reason for this difference is not known but it might be associated with the difference in the product-of-inertia term  $K_{xz}$  which results from the difference in yawing inertias between 2b and 3b. This point is covered further in the discussion of the calculated motions of figure 6. When the aileron deflection was increased from  $\pm 10^\circ$  to  $\pm 13^\circ$ , the control characteristics for condition 3b were comparable to those for condition 2b.

Increasing the moments of inertia made the adverse yawing with ailerons alone control appear to be either greater or less than that for the basic condition depending upon the amplitude of the disturbance. For small disturbances the high inertia tended to delay the building up of the yawing motion so that the adverse yawing was less than that for the basic condition. For large disturbances, however, there was sufficient time for the yawing motion to build up and the high inertia tended to keep the model in a yawed attitude and thus made the adverse yawing appear worse. Consequently, for this condition of large disturbances at the high inertias, the use of coordinated rudder control with the ailerons produced a definite improvement in the controllability of the model.

Results of calculations to determine the rolling motion resulting from a rolling-moment coefficient of 0.01 applied for 0.4 second in one direction and then reversed for 0.4 second are presented in figure 6. The results are in agreement with flight tests in showing that the model rolls much slower with a given control deflection for the high-inertia conditions than for condition 1. For condition 1 when the control is reversed there appears to be little if any lag in the reversal of rolling velocity. For all the high-inertia conditions, however, there is an

appreciable lag between the reversal of control deflections and reversal of rolling velocity. This lag, which is, of course, directly associated with the increase in rolling inertia, was responsible in the flight tests for the increased time required to reach a given angle of bank or return to a wing-level attitude.

Although the initial portion of the calculated motions in general are similar for the high-inertia conditions, the subsequent motions are greatly different because of differences in oscillation damping, yawing, moments of inertia, and stability derivatives. The fact that the response to the control reversal is greater for condition 2b than for condition 3b might be related to the unexplained flight-test results which indicated that the response to aileron control was greater for condition 2b than for condition 3b. As pointed out previously, this result might be attributed to the difference in the product-of-inertia term  $K_{xz}$  between conditions 2b and 3b, because changes in  $K_{xz}$  produce changes in adverse yawing. Increasing the value of  $K_{xz}$  tends to increase the adverse yawing; whereas decreasing  $K_{xz}$  tends to decrease the adverse yawing. These changes in adverse yawing result from the fact that with a positive value of  $K_{xz}$  a positive rolling acceleration produces a negative (adverse) yawing moment. In the present investigation, this effect caused the initial rolling response of condition 2b to be less than that of condition 3b as shown by the calculated results of figure 6. On the other hand, the response of the model in returning from a banked attitude was increased probably because the adverse yawing of the model during the roll-off caused the model to have an initial favorable yaw for the return to wing-level flight. This increased initial response to a control reversal probably gave the pilot the impression that condition 2b was more responsive to controls than condition 3b.

The effect of product of inertia on adverse yawing was also observed in the investigation reported in reference 4. In that investigation, as  $K_{z_0}$  (and hence  $K_{xz}$ ) was increased, greater rudder travel was required for satisfactory control coordination but, as  $K_{x_0}$  was increased ( $K_{xz}$  decreased), less rudder travel was required.

#### General Flight Behavior

The general flight behavior for the model without ballast weights was considered to be good with the lateral oscillations well damped and the model responding rapidly to control deflections. As the moments of inertia were increased, the general flight behavior became worse for all the ballasted conditions with the worst flight behavior occurring for condition 3 and the best for condition 4. (See table II.) In general, the ratings of table II appear to indicate that the decrease in the

oscillatory stability was not the predominant factor influencing the pilot's opinion of the general flight behavior. The pilot found that the decrease in rolling acceleration accompanying the increase in inertias, which caused a lag in the model response to control and increased the time required to reach a given angle of bank, was more undesirable than the decreased damping.

As long as smooth flights were maintained, the model flew steadier at the increased inertias than at the lower moments of inertias. When the model was disturbed by a large gust or control deflection, however, the high moments of inertia increased the difficulty of returning to steady flight. In conditions 2 and 3 after a gust or control disturbance a lightly damped large-amplitude oscillation that the pilot at times inadvertently reinforced occurred. The lateral oscillation for the model in condition 4 was well damped and of small amplitude, and the motion of the model following a gust or control disturbance was less oscillatory so that the application of a corrective control could be made with less danger of getting in phase with the motion and, therefore, inadvertently building up the oscillation. The calculated results presented in figure 6 appear to verify these flight-test results for conditions 2, 3, and 4.

#### CONCLUDING REMARKS

The results of the investigation to determine the effect of mass distribution on the dynamic lateral stability are summarized in the following paragraphs. Since small changes in some of the mass and aerodynamic characteristics may cause considerable differences in the lateral stability of an airplane, the results apply only to a  $60^\circ$  triangular-wing airplane in the conditions for which the investigation was made.

1. Increasing the moments of inertia reduced the oscillatory stability of the model and reduced the rolling acceleration which caused a lag in response of the model to control deflection and increased the time required to reach a given angle of bank.

2. The general flight behavior became worse as the inertias were increased and the predominant factor affecting the pilot's opinion of the general flight behavior appeared to be the lateral controllability and not the oscillatory stability.

3. The change in the lateral-stability derivatives produced by the particular wing-tank configuration used in the tests caused an improvement in oscillatory stability that partly counteracted the detrimental effect of the increased inertia on the oscillatory stability.

4. Increasing the altitude from sea level to 30,000 feet caused a general reduction in the damping which resulted in the time required for the lateral oscillation to damp to one-half amplitude being approximately doubled for all conditions.

Langley Aeronautical Laboratory  
National Advisory Committee for Aeronautics  
Langley Field, Va.






## REFERENCES

1. Campbell, John P., and Seacord, Charles L., Jr.: The Effect of Mass Distribution on the Lateral Stability and Control Characteristics of an Airplane as Determined by Tests of a Model in the Free-Flight Tunnel. NACA Rep. 769, 1943.
2. Bamber, Millard J.: Effect of Some Present-Day Airplane Design Trends on Requirements for Lateral Stability. NACA TN 814, 1941.
3. Bryant, L. W., and Pugsley, A. G.: The Lateral Stability of Highly Loaded Aeroplanes. R. & M. No. 1840, British A.R.C., 1938.
4. Hewes, Donald E. The Effects of Mass Distribution on the Low-Speed Dynamic Lateral Stability and Control Characteristics of a Model with a  $45^\circ$  Sweptback Wing. NACA TN 2313, 1950.
5. Shortal, Joseph A., and Osterhout, Clayton J.: Preliminary Stability and Control Tests in the NACA Free-Flight Wind Tunnel and Correlation with Full-Scale Flight Tests. NACA TN 810, 1941.
6. Shortal, Joseph A., and Draper, John W.: Free-Flight-Tunnel Investigation of the Effect of the Fuselage Length and the Aspect Ratio and Size of the Vertical Tail on Lateral Stability and Control. NACA ARR 3D17, 1943.
7. Sternfield, Leonard: Some Consideration of the Lateral Stability of High-Speed Aircraft. NACA TN 1282, 1947.
8. Jones, Robert T.: The Influence of Lateral Stability on Disturbed Motions of an Airplane with Special Reference to the Motions Produced by Gusts. NACA Rep. 638, 1938.
9. Jones, Robert T.: A Simplified Application of the Method of Operators to the Calculation of Disturbed Motions of an Airplane. NACA Rep. 560, 1936.
10. Toll, Thomas A., and Queijo, M. J.: Approximate Relations and Charts for Low-Speed Stability Derivatives of Swept Wings. NACA TN 1581, 1948.
11. Campbell, John P. and Goodman, Alex: A Semiempirical Method for Estimating the Rolling Moment Due to Yawing of Airplanes. NACA TN 1984, 1949.

12. Jaquet, Byron M., and Brewer, Jack D.: Effects of Various Outboard and Central Fins on Low-Speed Static-Stability and Rolling Characteristics of a Triangular-Wing Model. NACA RM L9E18, 1949.
13. Anon.: Flying Qualities of Piloted Airplanes. U. S. Air Force Specifications No. 1815-B, June 1, 1948.
14. Anon.: Specification for Stability and Control Characteristics of Airplanes. SR-119A, Bur. Aero., April 7, 1945.



TABLE I  
MASS AND AERODYNAMIC PARAMETERS OF THE 60° TRIANGULAR WING MODEL USED IN DETERMINING THE PERIOD AND TIME TO DAMP TO ONE-HALF AMPLITUDE

Condition	Configuration	Weight (lb)	$I_{x_0}$ (slug- ft <sup>2</sup> )	$I_{y_0}$ (slug- ft <sup>2</sup> )	$K_{x_0}^2$	$K_{y_0}^2$	$\eta$ (deg)	$K_{x_1}^2$	$K_{y_1}^2$	$K_{xz}$	$C_{Y_B}$ (total)	$C_{Y_D}$ (total)	$C_{Y_P}$ (total)	$C_{Y_R}$ (total)	$C_{Y_Q}$ (total)	$C_{Y_P}$ (total)	$C_{Y_R}$ (total)	$C_{Y_Q}$ (total)	$\tan \gamma$	$C_L$	Sea level		30,000 feet		
																					$\mu_b$	$\frac{n}{\rho W}$	$\mu_b$	$\frac{n}{\rho W}$	
1		6.39	0.0276	0.1265	0.0204	0.0948	22.60	0.0313	0.0836	0.0254	-0.630	0.066	-0.100	0	0.026	-0.085	0	-0.119	0.082	-0.3640	0.65	10.80	0.535	28.98	0.874
2a 2b		9.73 13.91	.0832 .1585	.2876 .4904	.0412 .0537	.1400 .1660	22.60 22.60	.0537 .0702	.1251 .1490	.0351 .0389	-.630 -.630	.066 .066	-.100 -.100	0 0	.026 .026	-.085 -.085	0 0	-.119 -.119	.082 .082	-.3640 -.3640	.65 .65	16.30 23.60	.657 .788	— 63.11	— 1.890
3a 3b		11.64 11.64	.0990 .1585	.1999 .2594	.0400 .0643	.0810 .1092	22.60 22.60	.0461 .0703	.0749 .0992	.0145 .0145	-.630 -.630	.066 .066	-.100 -.100	0 0	.026 .026	-.085 -.085	0 0	-.119 -.119	.082 .082	-.3640 -.3640	.65 .65	19.70 19.70	.721 .721	— 53.10	— 1.180
4a 4b		9.48 13.95	.0810 .1585	.1780 .2499	.0405 .0537	.0885 .0846	21.1 21.1	.0467 .0537	.0823 .0806	.0160 .0104	-1.062 -1.062	.126 .126	-.126 -.126	0 0	.026 .026	-.123 -.123	0 0	-.132 -.132	.082 .082	-.3640 -.3640	.65 .65	16.10 23.60	.650 .787	— 63.11	— 1.890
5a 5b		9.48 14.55	.0771 .1585	.1780 .2594	.0384 .0515	.0885 .0846	22.60 22.60	.0479 .0562	.0829 .0793	.0178 .0117	-.630 -.630	.066 .066	-.100 -.100	0 0	.026 .026	-.085 -.085	0 0	-.119 -.119	.082 .082	-.3640 -.3640	.65 .65	16.10 24.70	.650 .808	— 66.20	— 1.322

Constants:  
 $b = 2.61$  ft  
 $S = 2.95$  sq ft  
 $\gamma = 20^\circ$   
 $\frac{1}{b} = 0.315$   
 $\frac{b}{S} = 0.060$






Tail contributions determined for yawing derivatives by following equations:

$$C_{Y_T} = \frac{b}{S} C_{Y_P}(\text{tail})$$

$$C_{Y_Q} = -2 \frac{1}{b} C_{Y_P}(\text{tail})$$

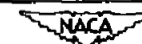


TABLE II  
 FLIGHT RATINGS AND CALCULATED PERIOD AND TIME TO DAMP TO ONE-HALF AMPLITUDE FOR THE 60° TRIANGULAR WING MODEL USED IN THE INVESTIGATION

Condition	Configuration	$\frac{k_{x_0}}{b}$	$\frac{k_{z_0}}{b}$	Sea level					30,000 Feet					Flight rating <sup>1</sup>		
				Oscillatory mode			Aperiodic mode		Oscillatory mode			Aperiodic mode		Oscillation damping	Lateral control	General flight behavior
				Period (sec)	$T_{1/2}$ (sec)	$C_{1/2}$ (cycles)	Rolling $T_{1/2}$ (sec)	Spiral $T_{1/2}$ (sec)	Period (sec)	$T_{1/2}$ (sec)	$C_{1/2}$ (sec)	Rolling $T_{1/2}$ (sec)	Spiral $T_{1/2}$ (sec)			
1		0.1422	0.3086	0.95	0.67	0.71	0.44	2.88	0.93	1.09	1.17	0.73	3.76	A	A	A
2a 2b		.2030	.3740	1.29	2.69	2.11	.56	4.13	1.48	12.02	8.14	1.14	9.60	B+	B	B
		.2310	.4070	1.46	6.61	4.54	.71	5.86								
3a 3b		.2000	.2820	1.24	2.37	1.91	.72	2.53	1.32	9.53	6.88	1.21	5.41	B+	B	B
		.2540	.3240	1.53	6.12	4.01	.76	3.16								
4a 4b		.2010	.2970	.97	1.17	1.20	.51	3.66	1.05	2.77	2.04	1.12	6.89	A-	B	B-
		.2310	.2910	1.05	1.68	1.61	.68	4.20								
5a 5b		.1960	.2970	1.22	1.97	1.62	.62	2.53	1.36	5.86	4.31	1.36	4.77	=	=	=
		.2270	.2910	1.36	3.56	2.62	.65	2.89								

<sup>1</sup>Oscillation damping, lateral control, and general flight behavior ratings:

- A Good
- B Fair
- C Poor
- D Unflyable



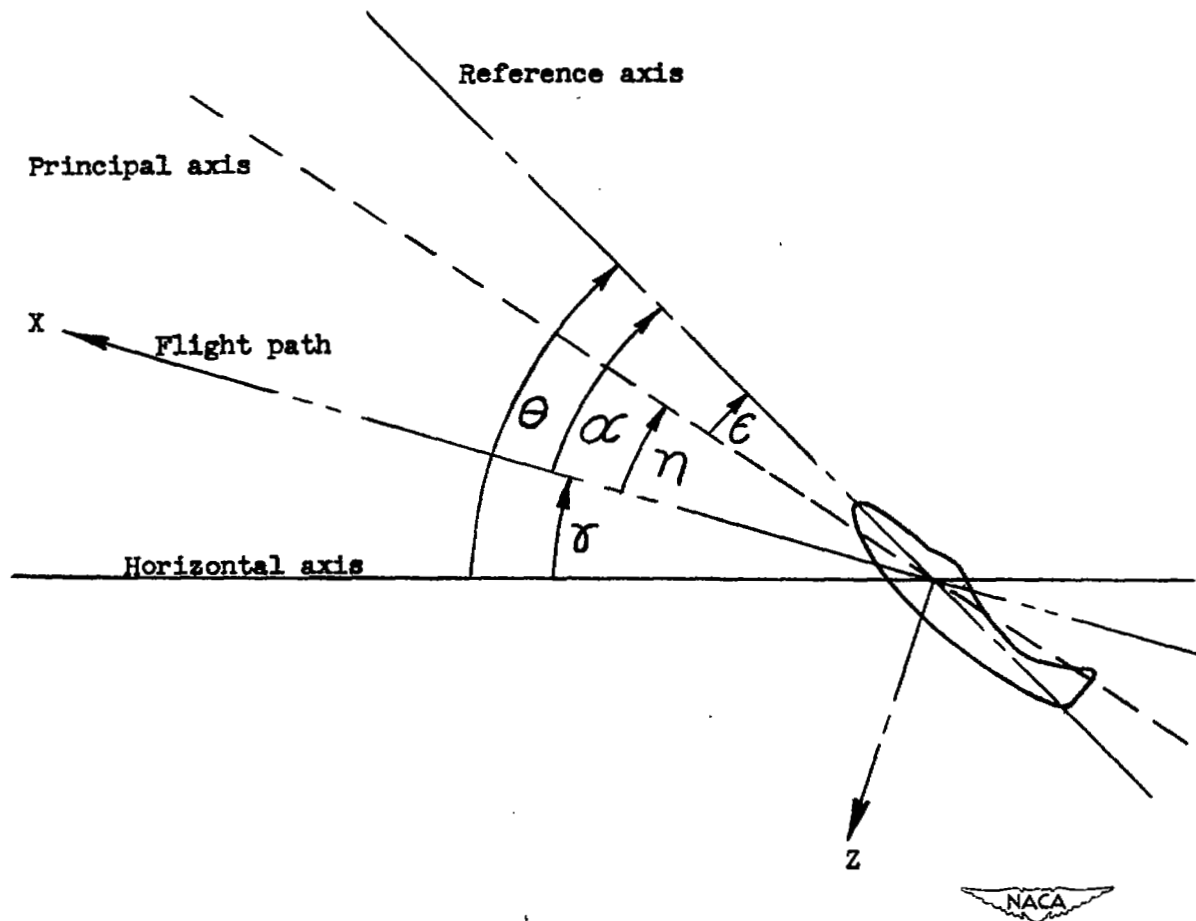


Figure 1.- System of axes and angular relationship in flight. Arrows indicate positive direction of angles.  $\eta = \theta - \gamma - \epsilon$ .

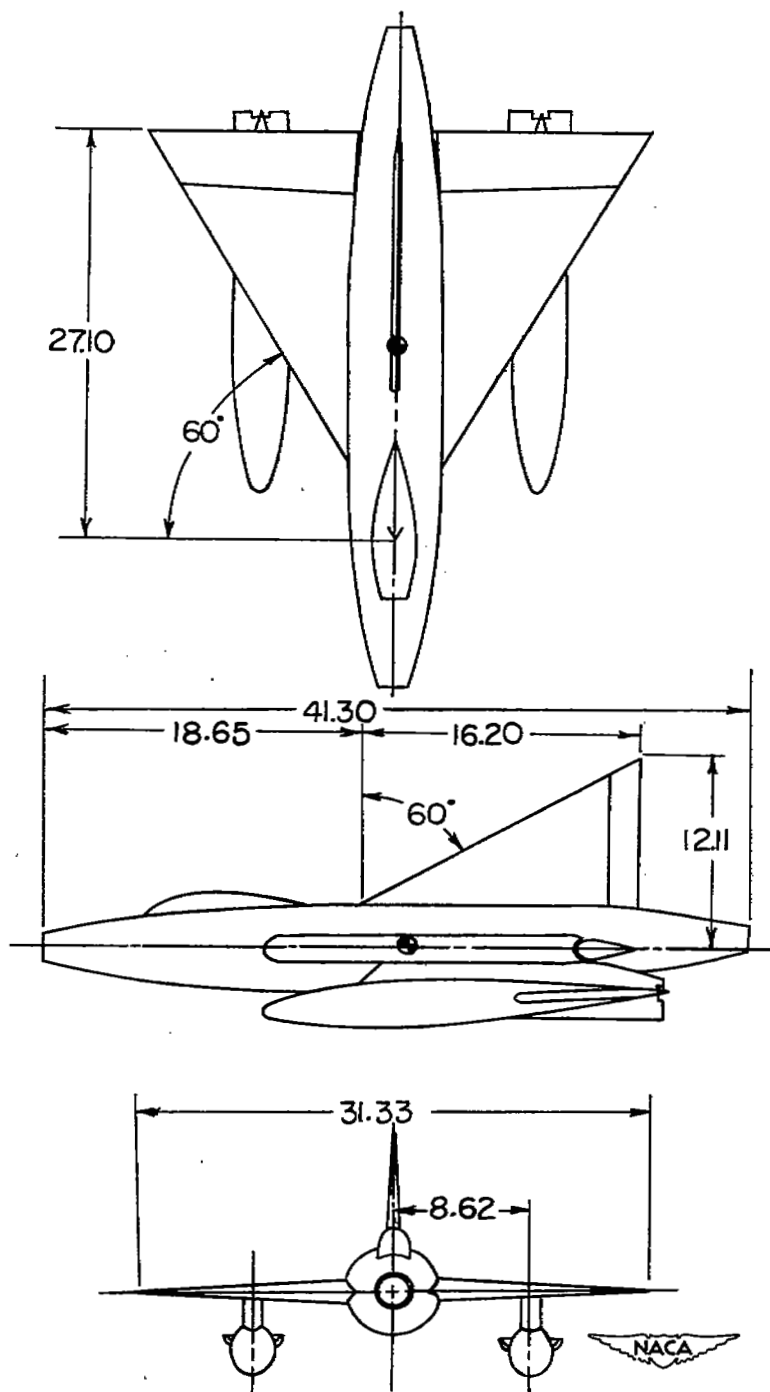


Figure 2.- Three-view drawing of a 60° triangular-wing model with wing tanks used in the Langley free-flight-tunnel investigation. All dimensions are in inches.

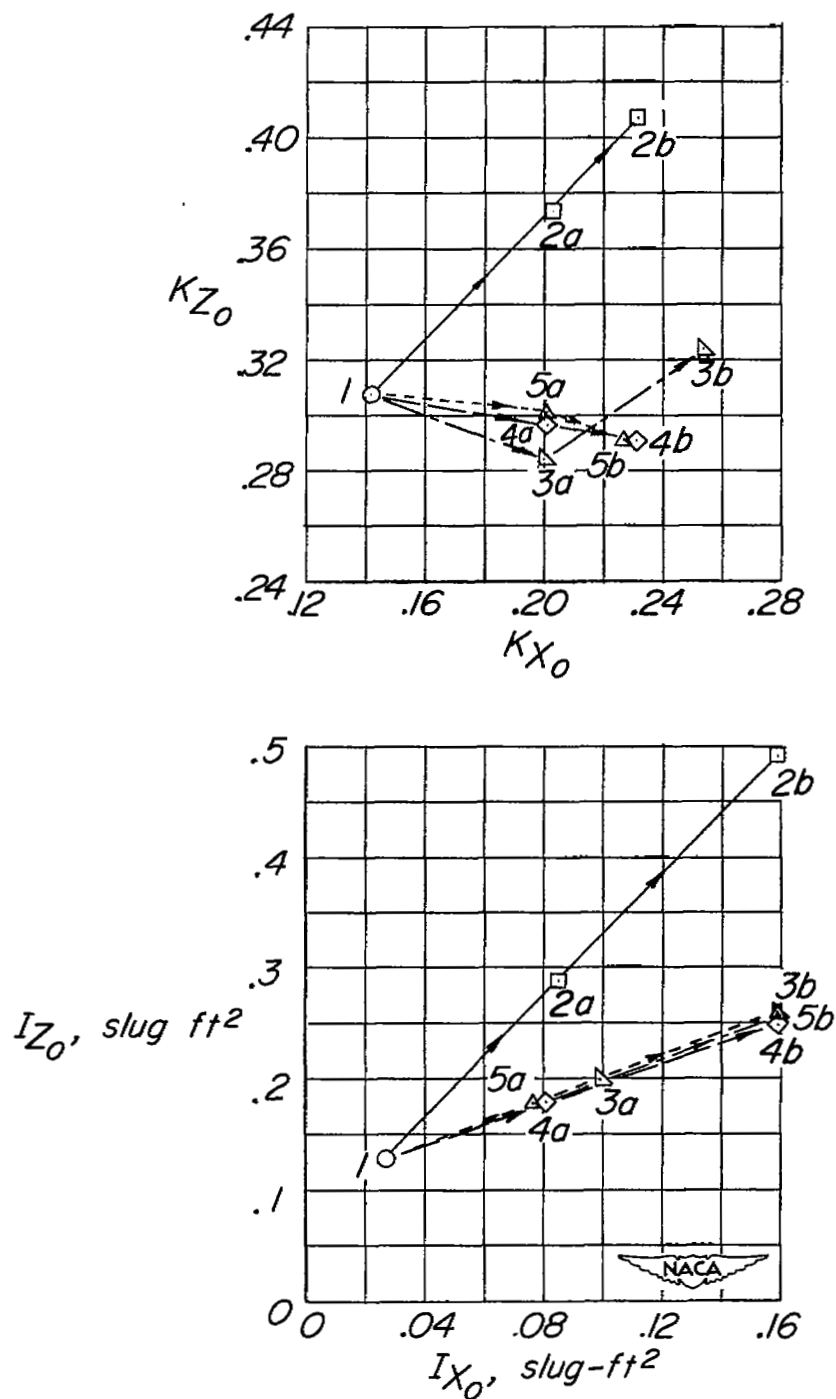


Figure 3.- Variation of the radius of gyration in roll and yaw and the moments of inertia in roll and yaw for the loading condition investigated.

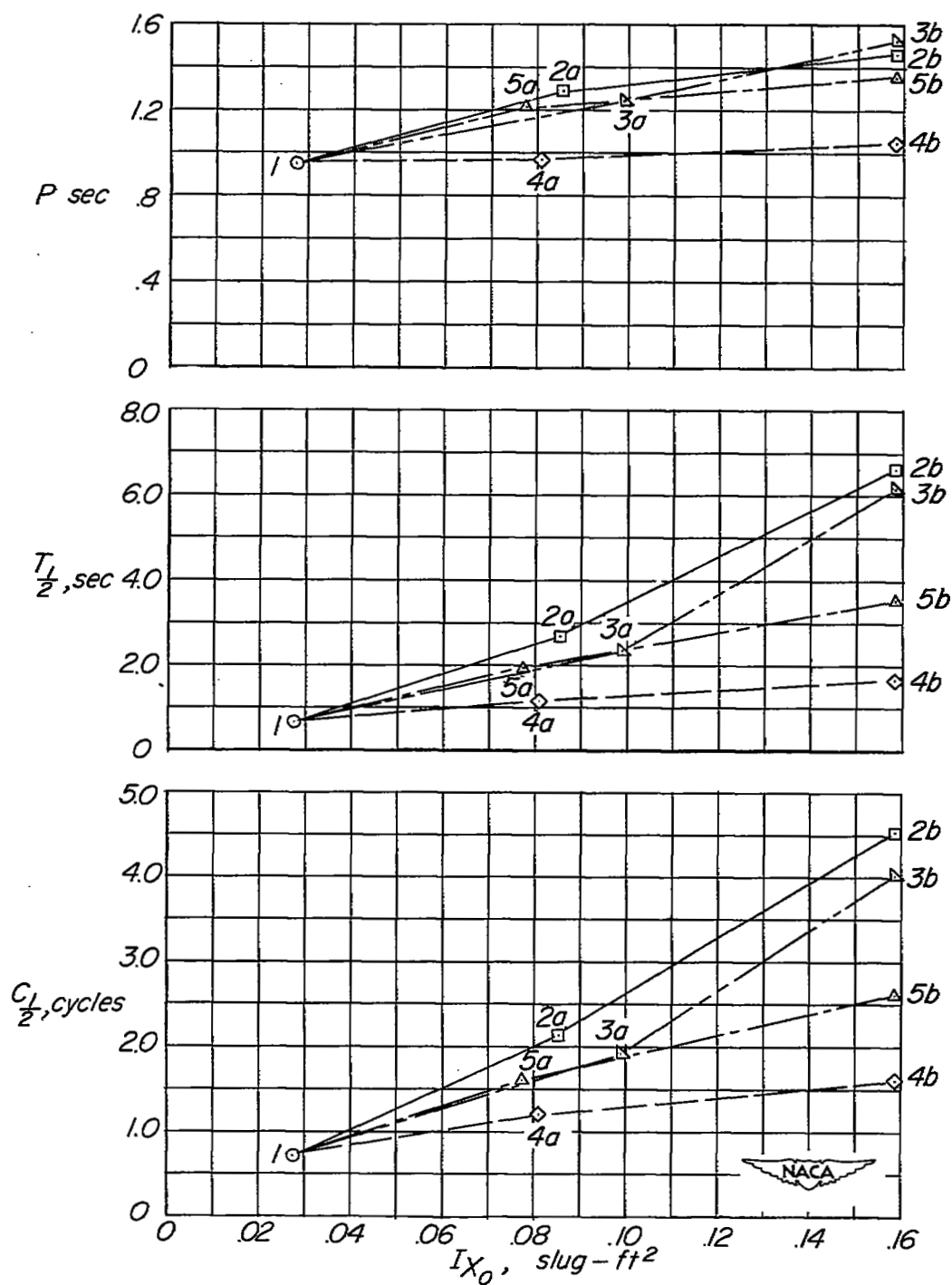


Figure 4.- Effect of increasing the moments of inertia in roll and yaw on the period and damping characteristics of the lateral oscillation. Sea-level condition.

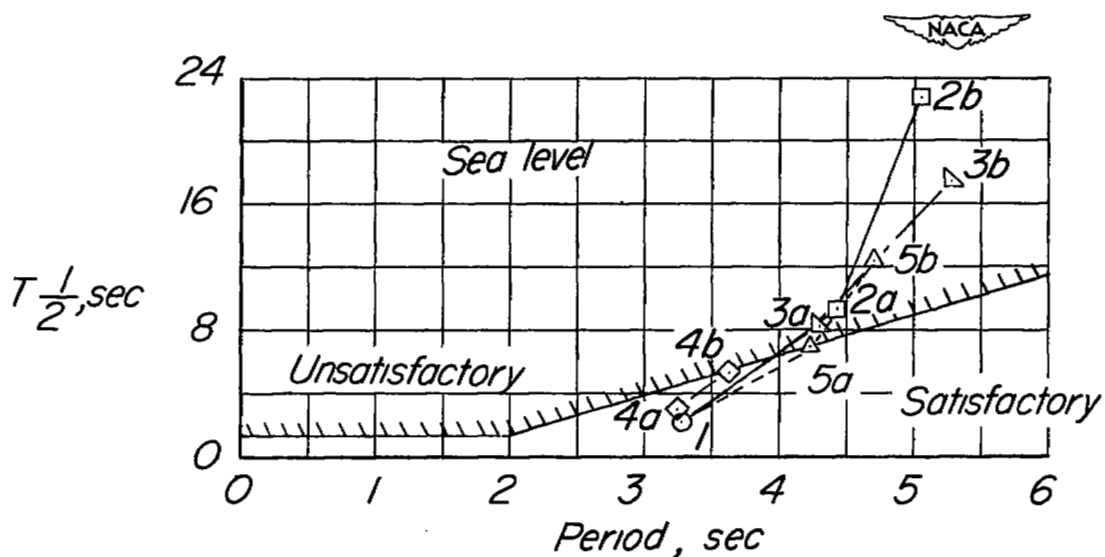
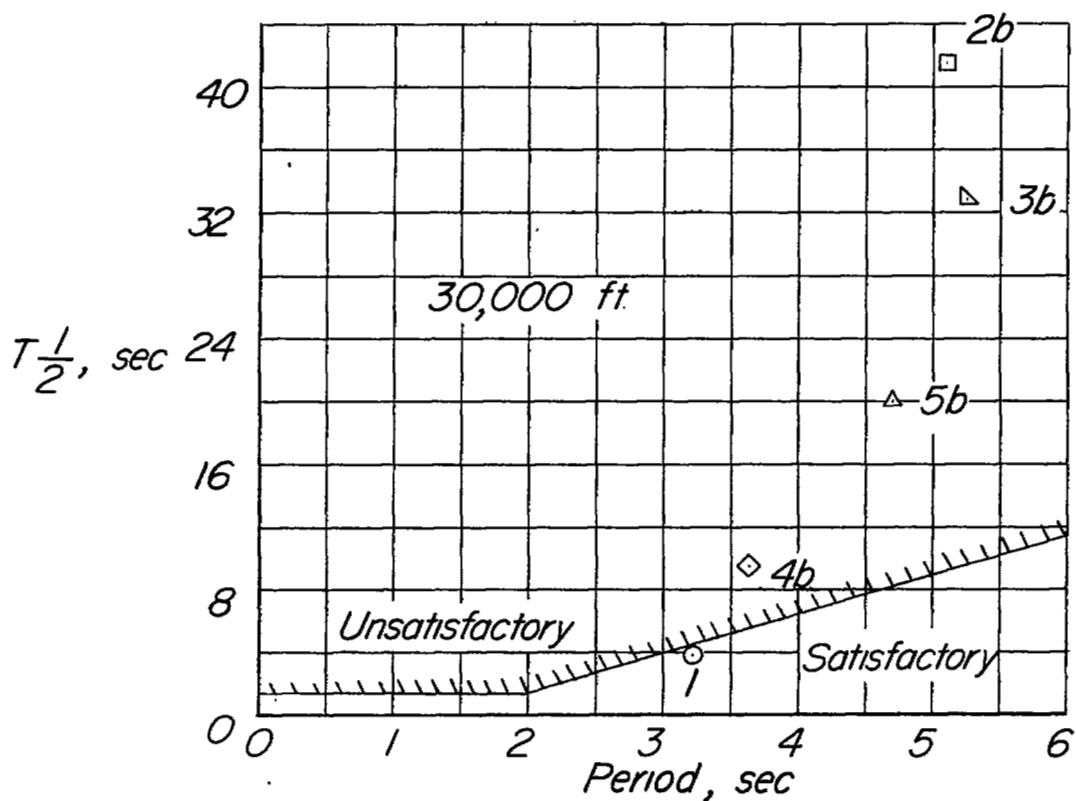


Figure 5.- Comparison of the scaled-up damping and period characteristics with the U. S. Air Force and Navy flying-qualities specification (references 13 and 14). Sea level and 30,000-foot altitude.

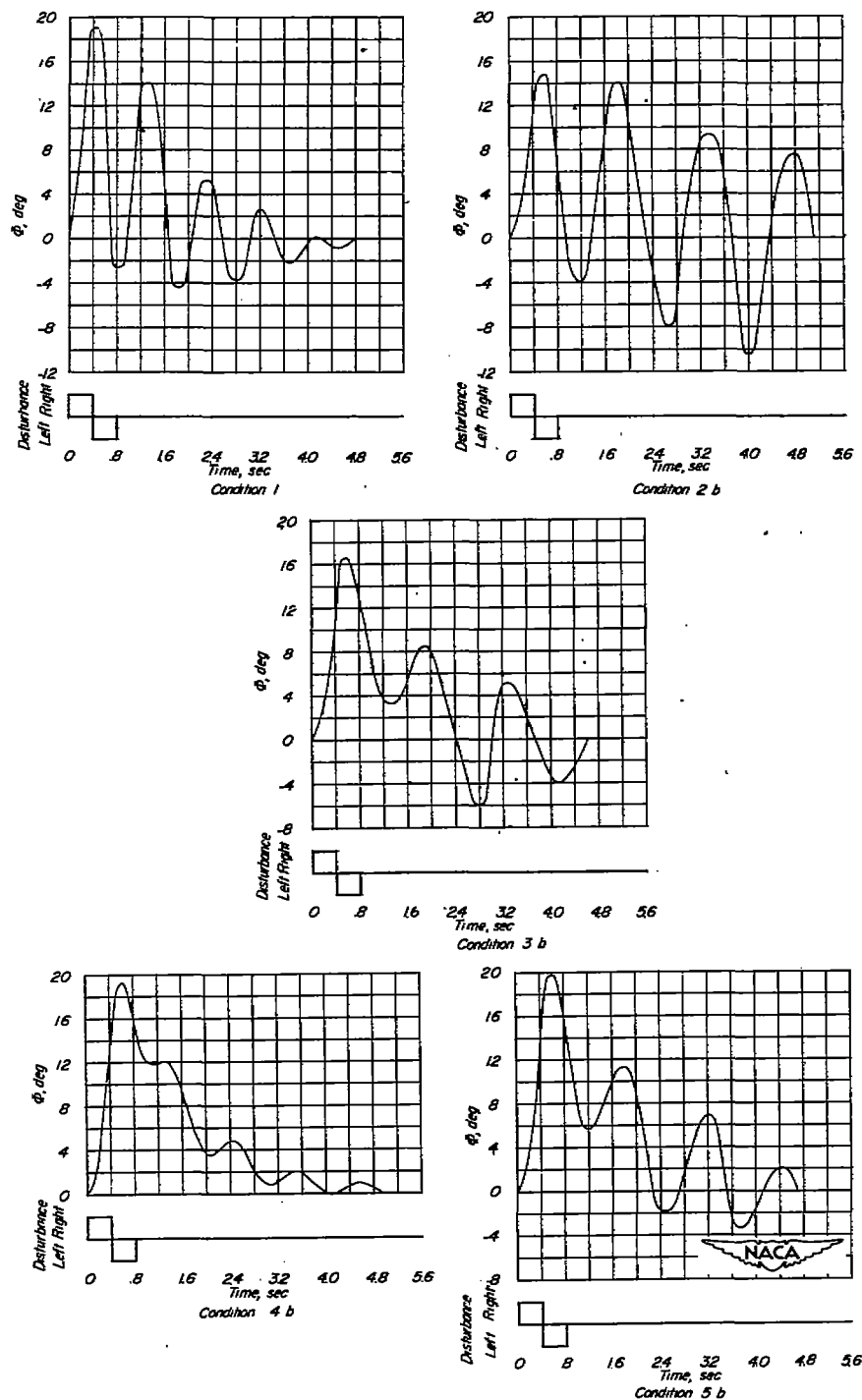


Figure 6.- Calculated rolling motion resulting from a rolling-moment coefficient of 0.01 applied for 0.4 second in one direction and then reversed for 0.4 second in the opposite direction. Sea-level condition.



NASA Technical Library



3 1176 01436 2546